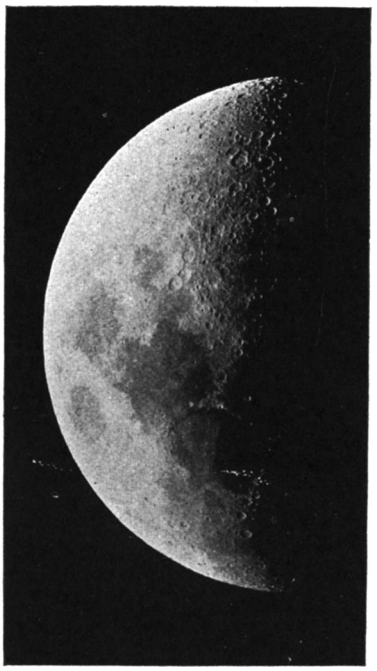
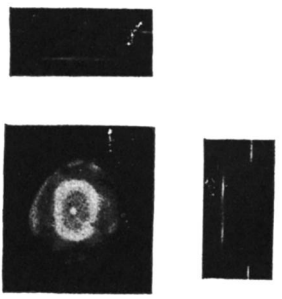
THE LUNAR CRATER ARCHIMEDES



THE MOON AT FIRST QUARTER



PLANETARY NEBULA N. G. C. 7662 AND SPECTRUM
LINE λ 5007

ON THE FORMS OF SPECTRAL LINES OBSERVED IN THE PLANETARY NEBULAE N. G. C. 7662 AND N. G. C. 2392

By W. W. Campbell and J. H. Moore

In our spectrographic observations for detecting rotational effects in the planetary nebulae, the spectral lines originating in the central portion of certain planetaries have been found to be double. A study of this phenomenon has been made, employing instruments of high dispersion, in the case of the two objects N. G. C. 7662 and N. G. C. 2392, in which the effect is quite marked, with a view to determining its probable origin and thereby obtaining some knowledge of the physical conditions which exist in the central region of these nebulae. Our results refer only to the effect observed in the N_1 (5007 A) and N_2 (4959A) lines of nebulium.

The accompanying illustration is a reproduction of a drawing of the planetary N. G. C. 7662 made by Dr. Curtis from short and long exposure photographs taken with the Crossley reflector. Above and on the right are placed photographs (on the same scale as the nebula) of the N_1 line obtained when the slit was placed respectively along the minor and major axes of the bright ring. The spectrograms are oriented with the violet toward the drawing of the nebula. The inner ends of the helium comparison line at 5015A are visible to the red of the N_1 line.

With the slit along the major axis of the nebula, the outer ends of the spectral lines show slight inclination to the zero direction; the brighter parts are noticeably inclined, while the central section taken as a whole, gives still greater inclination and in the opposite direction. The line obtained with the slit along the short axis considered in the same manner shows no inclination. The general form and inclination of the lines exhibit then the same characteristics which we have previously interpreted as due to a fairly rapid rotation of the central part of the nebula with smaller rotational velocities for the outer strata.

From our measures, the radial velocity of a point on the major axis at a distance of six seconds of arc from the center, with reference to that of the center, is about 5 km. per second. Assuming that this is the orbital velocity of a particle at this distance from the nucleus and adopting the recent value, by Van Maanen, of 0″.023 as the parallax of N. G. C. 7662 (corresponding to a distance

of 140 light years) we find the mass of the central portion of the nebula to be about 7.3 times that of the Sun. It should be noted that this is a minimum value of the mass, since we are probably not in the plane of rotation of the nebula.

It is found that in whatever position the slit is placed across the center of the nebular image, the central part of the spectral line is distinctly divided into two components. Moreover, the components show the same separation (about 0.8A) when the slit is placed along the major or minor axes, or upon an intermediate one. There is, however, considerable variation in the relative intensities of the components in these three positions. The spectral line on the right (illustration) shows a marked difference in the relative intensity of the red and violet components, and further the intensities are interchanged on opposite sides of the nucleus. With the slit along the short axis this difference in intensity of the components is not so marked although the less refrangible one appears somewhat stronger.

The most striking example of this phenomenon has been observed in N. G. C. 2392. With the slit of a one-prism spectrograph placed along the short axis of the nebula Professor Wright found the central section of the line strongly bowed toward the red. Our later spectrograms, secured with three-prism dispersion, show that the spectral line, in this position, is really double, the red component being very much stronger than the violet one. Along the major axis the form of line and relative intensities of components are similar to those for the corresponding position in N. G. C. 7662. In this nebula the line originating in the bright ring is also double, with a separation of the components of about 0.8A, while that at the center of the nebular line amounts to 1.7A.

All of the planetaries in which this peculiar form of line has been observed belong to a particular spectral type, given in the Harvard classification as Pe, or those in which the line at 4686A appears strong in the nebula. Nine objects of class Pe have been observed with high dispersion and seven of these appear to show the effect, with a suspicion of its existence in one other.

We have examined a number of hypotheses to account for the observed form of the lines, none of which can be regarded as perfectly satisfactory when investigated in detail. There is some indication that the effect may arise from a broadening of the central section of the line, from the motion of particles with

different velocities, or from a slightly increased pressure of the gases in the central region; and that the dark medial line is simply a reversal produced by the absorption of the outer layers.

The possibility has been considered that we may be dealing with the effect of a magnetic field upon the spectrum lines, known as the Zeeman effect; or that of an electric field, known as the Stark effect. Since the three prisms of our spectrograph reflect about 80% of a plane-polarized beam whose vibrations are parallel to the apex of the prisms, in placing the slit along the major and minor axes we have in effect been rotating an analyzer for polarized light, through 90°. We should then, on examining the light perpendicular to the direction of the field in either the Zeeman or Stark effects, obtain in one position the outer components, and in the other position the inner ones. Evidently the spectral lines here observed in the two positions do not correspond to the transverse effect of either the Zeeman or the Stark phenomenon. A number of tests have been made for the presence of circular or elliptical polarization of the components in the case of N. G. C. 7662, using in front of the slit, (*a*) a quarter-wave plate, (*b*) a Fresnel rhomb, or (*c* and *d*) either combined with a Nicol prism. In none of these have we been able to detect the presence of circularly or elliptically polarized rays, thus affording strong evidence that we are not observing a Zeeman effect in the direction of or at an angle to the field. The improbability of the existence in these objects of magnetic fields sufficient to produce separations of the component lines of 0.8A to 1.6A, together with the spectroscopic evidence, removes as a possible explanation of the phenomenon the simple Zeeman effect. As far as our observations go they cannot be said to furnish any evidence of or to exclude the possibility of the presence of the Stark effect, as our knowledge of the effect itself and of electrical conditions in the nebulae is very limited.

The present status of our feeling concerning these various hypotheses to account for the forms of the lines, can, perhaps, be summed up by saying that we look with favor upon the absorption theory, but that our minds are still open to the possibility of an explanation through some form of the Stark effect.